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Estimating the Abundance of Arboreal Forage Lichens: User's Guide

A Guide for Users of *Estimating the Abundance of Arboreal Forage Lichens*, Land Management Handbook Field Guide Insert 7

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BRITISH COLUMBIA
Ministry of Forests
Research Program

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Susan K. Stevenson, Art N. Lance, and Harold M. Armleder

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HOW USERS CAN CONTRIBUTE TO ADAPTIVE MANAGEMENT

The recommendations in this handbook are based on studies of arboreal lichen datasets collected from various sites in three regions of east-central British Columbia. Although these data proved to be fairly diverse, they represent only a small portion of the variety that occurs in mountain caribou ranges. Data from additional sites would help to fill in the picture of natural variation in arboreal lichen abundance. This would improve future recommendations for sampling and for management. Users of the lichen Field Guide are encouraged to assist this process by sharing the data they obtain using the methods recommended here. A form for submitting this information is found at the back of the handbook.

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Background

Arboreal lichens—lichens that grow on trees—are critically important winter forage for caribou in parts of British Columbia. Arboreal lichens grow abundantly on some old trees, but are generally sparse on young trees. Forest managers can make better decisions about whether, where, and how to log in caribou habitat if they have information about the abundance of these lichens.

The Field Guide, *Estimating the Abundance of Arboreal Forage Lichens*,[1] describes a method of estimating lichen abundance on individual trees. The Field Guide presents a series of photos of trees with known amounts of lichen below 4.5 m, which is the part of the tree within reach of caribou in winter. The user compares the tree being assessed to the photos, and scores it as belonging in Lichen Class 0–5. The Field Guide is quick and relatively simple to use, can give similar results when used by different people, and produces assessments that are related to actual lichen biomass.

The Field Guide, however, does not offer direction on how lichen assessments fit into planning and data collection processes. It does not discuss how to sample or what to do with the data collected. This handbook is intended to fill those gaps, and help managers use the Field Guide as a tool for planning in caribou habitat. The Field Guide also has research and inventory applications, and can be used to monitor the effects of forestry practices on lichen abundance.

This handbook is based on analysis of several datasets collected during the first two years after the Field Guide was published. These include data from one reconnaissance-level project, in which several sampling methods were compared, and several block-level datasets collected for research or operational forestry purposes. The data were collected in the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zone[2] in three Ministry of Forests Regions. As more data become available from more places, the characteristics of lichen data can be described more fully. The recommendations in this handbook may then be extended and refined.

1 Armleder, H.M., S.K. Stevenson, and S.D. Walker. 1992. *Estimating the Abundance of Arboreal Forage Lichens.* B.C. Ministry of Forests, Land Management Handbook Field Guide Insert 7. Victoria, B.C.

2 Meidinger, D. and J. Pojar. 1991. *Ecosystems of British Columbia.* B.C. Ministry of Forests, Special Rep. Ser. No. 6. Victoria, B.C.

Who is the handbook for?

This handbook is intended for people who plan forestry activities in caribou habitat.

At the reconnaissance level, it is intended for people who:

- design fieldwork for plans such as Forest Development Plans, Landscape Unit Plans, Total Resource Use Plans, or Local Resource Use Plans
- compile and interpret data for those plans

At the block level, it is intended for people who:

- plan timber cruising or data collection for Silviculture Prescriptions
- develop Silviculture Prescriptions for selection harvesting blocks in caribou habitat

At both levels, it is for people who:

- train and supervise crews that collect resource data

It may also be used by researchers studying the distribution and abundance of arboreal lichens, or the impacts of management activities on the lichens.

THIS HANDBOOK IS INTENDED TO HELP MANAGERS:

- **plan and carry out data collection using the lichen abundance Field Guide**
- **use the data as a tool for planning in caribou habitat**

Where can it be used?

The Field Guide was developed for use in the ESSF biogeoclimatic zone. There, the snowpack is often as much as 3 m deep, which allows caribou to reach lichens up to 4.5 m. This level was used in the Field Guide as the upper limit for estimating lichen abundance.

Caribou use arboreal lichens from the lower branches of trees in other biogeoclimatic zones as well. The Field Guide may be used in any zone where it is important to assess lichen abundance on the lower 4.5 m of trees. However, users should be aware that:

- Only the lichens within about 1.5 m of the top of a settled snowpack are available to caribou.
- Trees in other forest types may not look like the trees in the photos. For example, lodgepole pine in the Montane Spruce (MS) zone may have few branches below 4.5 m, but support a dense lichen cover on the trunks.

Users should not assume that assessments based on the Field Guide are good indexes of lichen abundance on entire trees. Lichen abundance in the lower 4.5 m of a tree is not necessarily well correlated with lichen abundance in the rest of the crown.

In the ESSF zone, the deep snowpack allows caribou to reach lichens on the lower branches of trees.

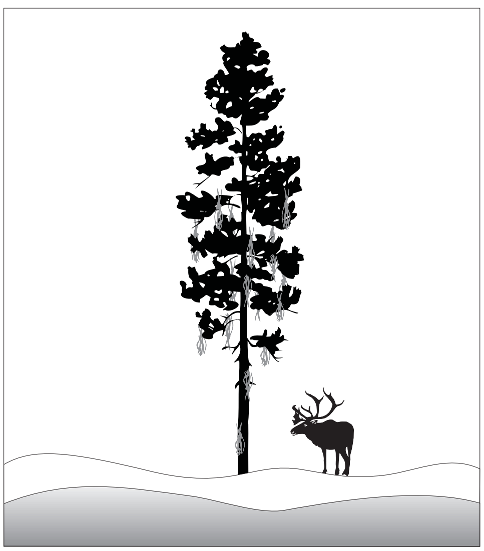
The Field Guide was developed for use in the ESSF, but it may be used in any zone where it is important to assess lichen abundance on the lower 4.5 m of trees.

Caribou depend on lichens for winter forage

Arboreal lichens form part of the winter diet of caribou in many parts of British Columbia. The caribou of southeastern and east-central British Columbia, known as **mountain caribou**, are especially dependent on arboreal lichens. For caribou living elsewhere in British Columbia, often called **northern caribou**, arboreal lichens are one of several important winter foods. The two types of caribou belong to the same species, but occupy different winter habitats (Figure 1).

With their well-insulated coats and large hooves, caribou are well adapted to cold weather and deep snow. **Mountain caribou** have an unusual strategy for surviving the long, snowy winters. Unlike moose and deer, which seek out shallow snow, mountain caribou spend much of the winter in high-elevation forests. Deep snowpacks at high elevations bury other forage that caribou might use but also create a platform that allows the caribou to reach higher into the trees. This strategy of spending winter at high elevations has the advantage of separating the caribou from moose, deer, and wolves most of the time, but it does make them dependent on a single type of forage—arboreal lichens.

Mountain caribou do not necessarily spend the entire winter in the high-elevation ESSF zone. In some areas they also use the lower-elevation Interior Cedar–Hemlock (ICH) zone, especially during early winter when the snow is fresh and soft. In the ICH zone, caribou usually cannot reach many lichens on the lower branches of trees, and instead eat lichens that have fallen onto the snow or are available on fallen branches or fallen trees. They also eat the leaves of low evergreen shrubs such as falsebox or bunchberry. Unlike moose and deer, caribou browse very little on woody parts of shrubs. Assessment of winter forage for caribou in the ICH zone should include litterfall lichens, lichens on fallen trees, and vascular forage, as well as lichens in the lower canopy.



In the MS zone, more lichens may be available to caribou on the trunk of lodgepole pine than on the branches.

Elsewhere in British Columbia, where the snowpack is not as deep, **northern caribou** can scrape away snow to get at other types of forage during winter—in particular, terrestrial (ground) lichens, grasses, and sedges. Northern caribou use arboreal lichens too, but not as regularly as do mountain caribou. Terrestrial vegetation may become inaccessible when the snow is deep or crusted, and northern caribou then move to forest types where they can feed mainly on arboreal lichens. Sometimes northern caribou switch back and forth between terrestrial vegetation and arboreal lichens in a single forest type.

People sometimes wonder whether it makes any difference to caribou if the lichen supply is reduced by logging, since arboreal lichens seem to be abundant and widespread in caribou range. Most studies of caribou in British Columbia have concluded that caribou numbers are not directly limited by the amount of food available to them. What seems to be more important is the amount of suitable habitat available at different times of the year. During winter, caribou tend to range over large areas, moving frequently and unpredictably. This behaviour makes it difficult for predators to find them. The amount of space they need to avoid

predators is probably greater than the amount they need just for foraging. However, to serve as suitable habitat for avoiding predators, an area must also provide accessible food. Accessibility varies with depth and density of snow. To maintain caribou populations, managers must ensure that large areas with accessible forage are available in the right places at the right times.

Information about lichens may be required for approval of plans

Increasingly, the B.C. Ministry of Environment, Lands and Parks is requiring that caribou habitat be considered in forest management plans. Information on lichen abundance is an important input to management decisions in a planning area that includes caribou range. In some areas, information about lichens may be requested before a management plan is submitted, or may increase the likelihood that the plan will be approved.

In several regions, Ministry of Environment, Lands and Parks guidelines call for use of selection silvicultural systems to maintain caribou habitat in certain areas. Some land-use plans now specify partial cutting or "modified" harvesting instead of clearcutting in caribou range. In such cases, information on lichen abundance may be essential to the design of suitable Silviculture Prescriptions.

In the ICH zone, more lichens may be available on fallen trees or branches than are within reach on standing trees.

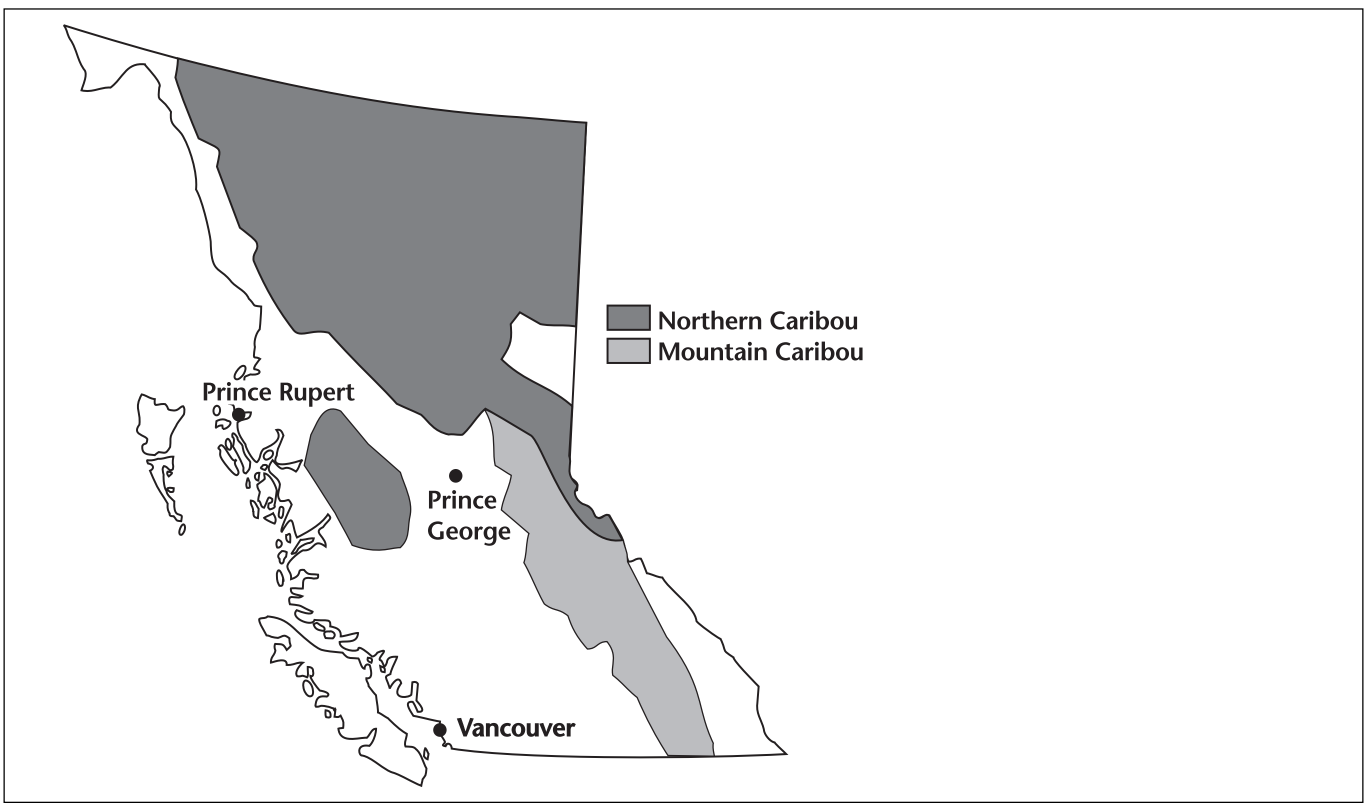
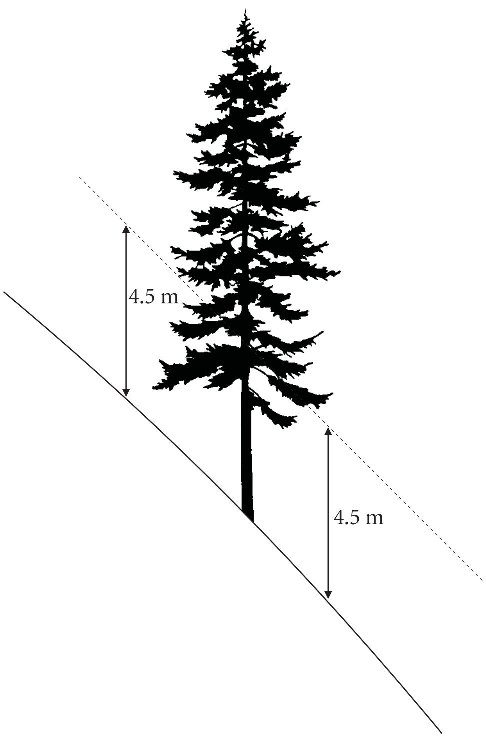


figure 1 *Range of caribou in British Columbia.*



Remember that the photo guide shows trees that are on the boundary between lichen classes.

Basic procedures

The Field Guide is easy to use, but it is important that it be used in the same way from day to day and by all crew members.

- Practice together to develop consistency. At the beginning of a project, all users should practice together until their results are converging. As there will always be trees at the borderline between Lichen Classes, there will always be some discrepancies between the scores given by different observers. If training and practice have been adequate, it is reasonable to expect that most observers will give the same tree the same score, and that scores that do differ will not differ by more than one Lichen Class.
- Know the sampling scheme and follow it rigorously. To avoid bias, users must score *all* the sample trees, and *only* those trees. Dying and dead sample trees are also assessed. Unusual trees that occur outside the plot or transect may be described in the field notes, but must not be added to the data.
- Walk around the tree to find the best viewing position. The lichen estimate applies to the entire lower portion of the tree, not just to one side. Lichen abundance may look different from different angles. The photographs in the Field Guide were taken from the angle that best revealed the lichens. The best viewing position is the one from which you can see the lichens best, with the least interference from other trees. If you cannot see all the lichens from one viewing position, you must adjust your estimate to account for the additional lichens viewed from a different position.
- Include all lichens below 4.5 m in the assessment. This includes lichens on the trunk of the tree, and on branches that originate above 4.5 m, but hang down into the zone of lichen estimation.

  On sloping ground, the 4.5-m line runs parallel to the slope. Caribou can reach higher into the canopy on the uphill side of the tree than on the downhill side of the tree.

  In the Field Guide photos, 4.5 m is indicated by the red mark at the top of the height pole.
- Keep referring to the Field Guide. To use the Field Guide, first decide which photo series—A, B, or C—best matches the tree. Use it to determine roughly into which class the tree fits. Then confirm your assessment by turning to the photos that distinguish the classes. Remember that *all* the photos in the Field Guide show trees at the *boundary* between Lichen Classes. If you classify a tree as Class 4, for example, it should have *more* lichen than the trees on pages 16–17 of the Field Guide, and *less* lichen than the trees on pages 18–19.

When you have some experience, you may be able to skip the first photo series A–C and go directly to the second set of photos. However, to prevent your estimates from “wandering,” it is important to confirm your assessment by referring to the photos. Even experienced users should refer to the photo guide several times a day, and more frequently where lichen abundance is especially variable.

Questions and answers

Can lichen assessments be done at any time of year?

Lichen assessments are best done during the snowfree season. As the 4.5-m point is always located relative to the forest floor, it is easiest to identify when there is no snowpack. Also, assessments can be difficult when fresh snow has accumulated on branches.

Some of these trees have hardly any lichens on them. Do I have to assess them?

Yes. The aim is to find out how many trees are present in each Lichen Class, not just to look for trees with a lot of lichen. To avoid biasing the results, each tree that is identified as a sample tree must be assessed, regardless of how much lichen is on it.

If you are assessing trees with very little lichen, remember that a tree with only a wisp of lichen belongs in Class 1, not Class 0. Lichen Class 0 is reserved for trees with no lichen at all. This is extremely rare in most stands where lichen assessments are done. Class 0 is included in the scheme because it is logical to allow for the possibility of trees with no lichen at all, and because there are some occasions when it is actually needed.

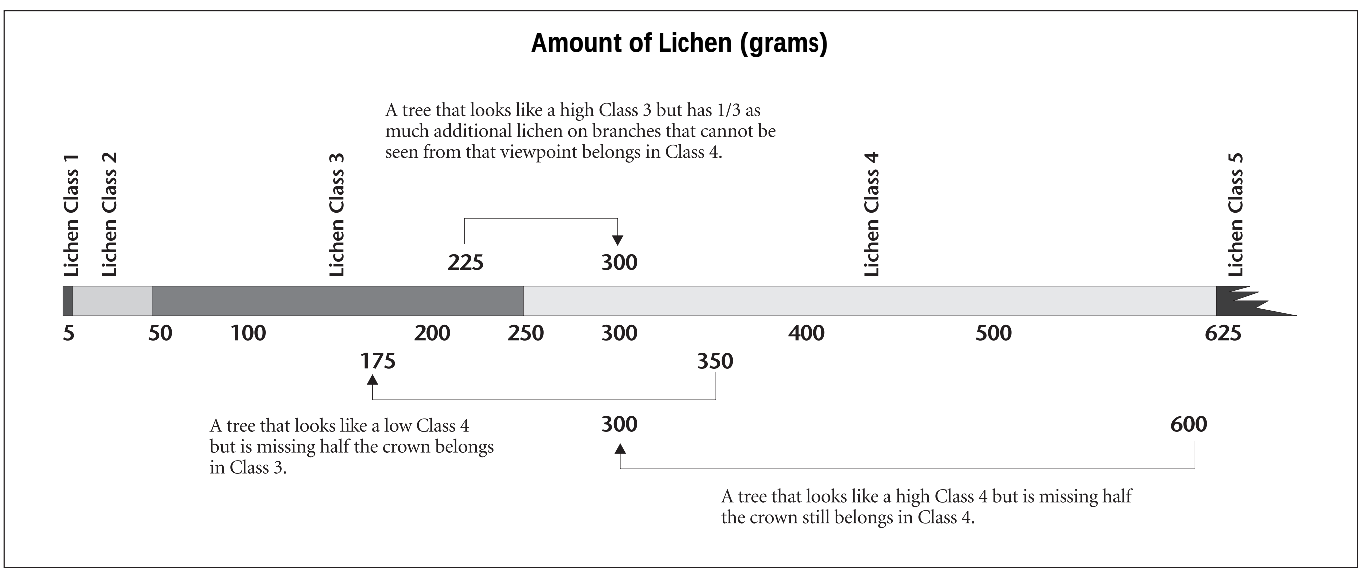
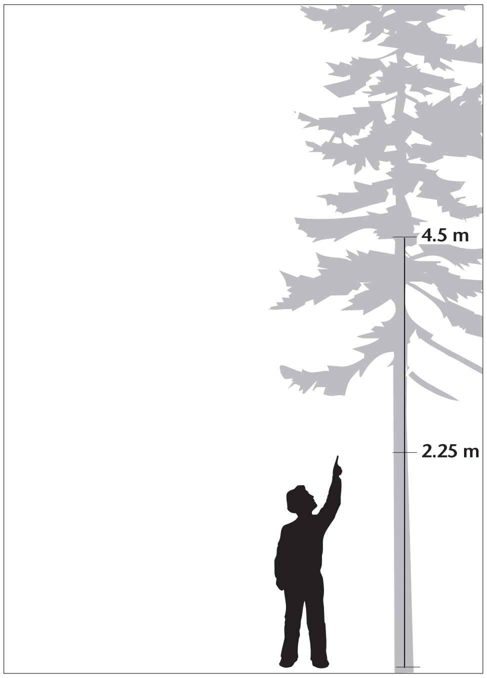
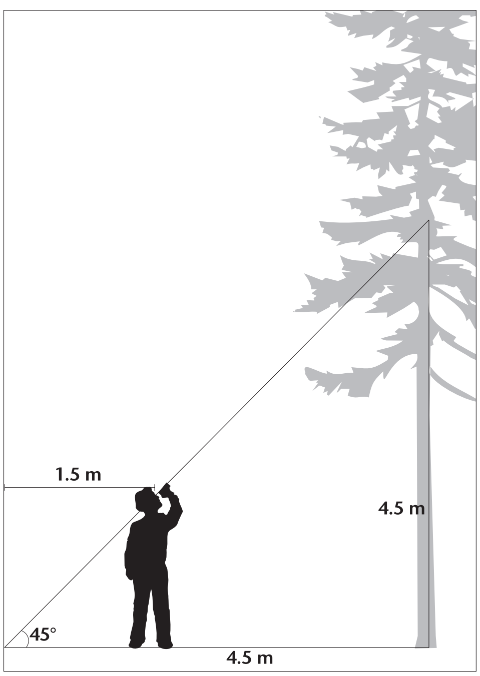


figure 2 *How to use the scale to adjust lichen scores.*



The 4.5-m point can be estimated with reference to the height of a person.



A clinometer can be used to identify the 4.5-m point.

There are more lichens on one side of the tree than the other. Which side do I look at when I assess the tree?

It helps to understand that the Field Guide photographs were taken so that as many of the lichens as possible would be visible. Some of the lichens that could not be seen were removed before the photos were taken. Thus, the lichens that make up the biomass values given on page 21 in the Field Guide are all, or nearly all, visible in the photos.

Usually, it is adequate to position yourself so that you can see as much of the lichen as possible, and score the tree on the basis of what you see. If a substantial amount of lichen cannot be seen from that position, you may need to adjust the class upward. Suppose, for example, you are assessing a tree that looks like a high Class 3, but your estimate does not take into account some branches that were invisible from your viewing position. You estimate that those branches support about one-third as much lichen as the portion of the tree you have already estimated. Use the scale on pages 4–5 of the Field Guide to determine whether the additional lichen will move your estimate to Class 4 (Figure 2).

Sometimes it is necessary to make allowances for a tree with an asymmetrical crown. Again, use the scale on pages 4–5 of the Field Guide to make the adjustment.

How important is it to identify the 4.5-m point accurately?

For most purposes, the 4.5-m point can be estimated without an aid. If lichen abundance is being assessed repeatedly on the same trees, it is more important to locate the 4.5-m point consistently.

You can use a height pole, or cut a stick that reaches to 4.5 m when held above the head, or use another person for reference. A 178-cm (5´11´´) person standing with one arm extended upwards has a reach of about 2.25 m, or half the height of the lichen estimation zone.

If you are not working with a partner, you can position yourself at a horizontal distance of 4.5 m less your eye height from the tree, and use a clinometer to find the point on the trunk at a 45° (100%) angle from your viewing position.

Some trees I have to assess don't look like the trees in the photos. How do I assess them?

Some trees, such as snags or pines, look very different from the trees in the photographs. They may have all the lichens clumped on a few small dead branches and on the trunk. To assess such trees, it may help to use the 5-gram clumps provided for reference on each tree photo. The relationship between Lichen Class and number of 5-g clumps on a tree is shown on page 21 of the Field Guide.

It is hard to tell the difference between Classes 1, 2, and 3 from the photographs. Is there any other way to classify trees with low lichen abundance?

Trees with low lichen abundance, as well as trees that do not look like the ones in the photos, can be assessed by counting the number of 5-g clumps that are present below 4.5 m. Page 21 of the Field Guide shows photos of 5-g clumps, and relates the number of clumps to Lichen Class.

How do we know how much lichen is really on the trees in the photographs?

The lichens on the trees in the photos were removed in stages, air-dried to room temperature, and weighed. First, some of the branches and lichens that were invisible to the camera were removed, and the tree was photographed. Then, a portion of the remaining lichens was removed from each part of the tree, bagged, and labelled, and the tree was photographed again. This process was repeated until a series of photographs had been taken, and all the lichens had been removed. The lichens in the bags were weighed, and the information used to calculate the biomass of the lichens present on the tree in each photo.

How accurately can observers classify lichen abundance on trees?

This question is being answered as part of an ongoing study of arboreal lichen ecology near Prince George. An experienced observer used the Field Guide to assess lichen abundance on 27 Engelmann spruce and subalpine fir trees. Lichen abundance in the assessment zone of each tree was then determined through detailed sampling and weighing. Figure 3 shows how the Lichen Class assigned by the observer compared to the Lichen Class based on biomass sampling.

Although most trees were classified correctly, the errors that did occur were nearly all underestimates rather than overestimates. This pattern is consistent with the results of other studies in which estimates of lichen biomass have been related to actual measurements. It probably occurs because people are more likely to miss seeing lichens that are present than to imagine lichens that are not there. To some extent, observers can compensate for this tendency by being aware of it.

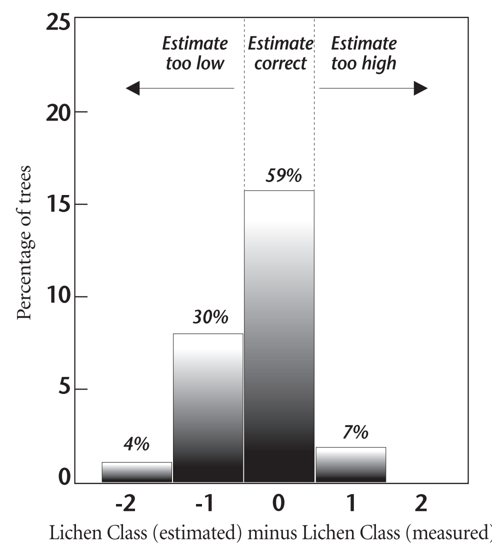


figure 3 *Frequency distribution of the difference between Lichen Class based on measured samples and Lichen Class assessed by an observer.*

How much lichen must a tree have for caribou to use it?

Research into the foraging behaviour of caribou indicates that caribou are more likely to feed from trees with abundant lichens than trees on which lichen is sparse.[3] The Field Guide was not used to assess lichen abundance on the trees in those studies. Based on their experience,

3 Terry, E. 1994. *Winter habitat selection and foraging patterns of mountain caribou.* MSc thesis. University of British Columbia, Vancouver, B.C.; Rominger, E.M., C.T. Robbins, and M.A. Evans. 1996. *Winter foraging ecology of woodland caribou in northeastern Washington.* J. Wildl. Manage. 60(4):719–728.

however, the researchers judged that trees in Lichen Classes 0, 1, and 2 in the Field Guide were likely to be passed by, whereas trees in Lichen Class 3 or higher were potential feeding sites.

Should I collect information on the types of lichens that are present, and if so, how?

There are important differences between the two types of forage lichen —*Alectoria* and *Bryoria*—that can affect forest management in caribou habitat. First, the two types seem to prefer different combinations of light and moisture, and *Bryoria* is likely to respond more positively than *Alectoria* when stands are opened up by partial cutting. Second, there is growing evidence that caribou choose *Bryoria* rather than *Alectoria* when both are available.[4] Information collected on the types of lichens present will contribute to a knowledge base that can be used to improve management.

For most purposes, it is adequate to classify the sample trees into one of three categories, such as:

- A — mainly *Alectoria* (more than 70% *Alectoria*)
- AB — mixed *Alectoria* and *Bryoria*
- B — mainly *Bryoria* (more than 70% *Bryoria*)

The photographs on page 3 of the Field Guide will help.

If more detailed assessments are needed, genus composition may be estimated to the nearest 10%. Genus composition is usually recorded only for trees of Lichen Class 2 or more.

How can I tell *Alectoria* and *Bryoria* from other lichens?

In the ESSF zone, *Alectoria* and *Bryoria* are the dominant beard-like lichens growing on trees. In other zones, you are more likely to encounter lichens that could be confused with *Alectoria* and *Bryoria*.

Bryoria species are brownish, greyish, or almost black, with branches that are round in cross-section, not flattened. Several reddish brown species have recently been renamed as *Nodobryoria*; they should be included with *Bryoria* in lichen assessments.

Alectoria sarmentosa is yellow-green to grey-green. Some *Usnea* species look similar, but have a tough central cord that is noticeable when a fragment is gently pulled apart. *Ramalina thrausta* looks similar, but the branches have hook-shaped tips.

Most often, users of the Field Guide will not need to carry out detailed lichen identification. Similar-looking species may be lumped with *Alectoria* and *Bryoria* for the purposes of determining Lichen Classes. Users who would like to learn more about lichen identification may consult a Field Guide.[5]

4 Rominger, E.M., C.T. Robbins, and M.A. Evans. 1996. *Winter foraging ecology of woodland caribou in northeastern Washington*. J. Wildl. Manage. 60(4):719–728.

5 McCune, B. and T. Goward. 1995. *Macrolichens of the northern Rocky Mountains.* Mad River Press Inc., Eureka, Calif.; Vitt, D.H., J.E. Marsh, and R.B. Bovey. 1988. *Mosses, lichens and ferns of northwest North America.* Lone Pine, Edmonton, Alta.

The frequency distribution of actual lichen biomass on trees in a typical ESSF stand is strongly asymmetrical; there are more trees with small amounts of lichen than with large amounts.

When lichen abundance is rated using the Field Guide, the data tend to be more symmetrical, resembling a normal (bell-shaped) distribution. However, the appearance of a normal distribution is artificial. It results from using Lichen Class scores with an equal interval between them (1,2,3, etc.) to represent different-sized ranges in biomass (0–5, 5–50, 50–250, etc.).[6]

This has important consequences for data analysis. Usually, once a dataset of any type has been obtained, the next step is to summarize it with a single value such as the mean or the mode (most prevalent score) to represent the data as a whole. **This is not recommended for lichen scores, particularly if the aim is to estimate lichen biomass.** There are two reasons for this. One is the non-linear relationship between scores and biomass; scores of 2 and 4 differ equally from a mean score of 3 but they do not correspond to equal differences in biomass. The second reason has to do with the way caribou forage. If trees scoring 3 or more are chosen for feeding, but trees scoring 1 or 2 are ignored, the mean score for all trees combined would be a poor measure of their relative value to caribou. A better measure would be the number of trees with scores of 3 or more. Such information is lost when the data are merged or simplified into a composite value, such as the mean.

Therefore, when a set of lichen scores is summarized, an important piece of information to retain is *the relative abundance of different scores*. This can be done by compiling the data as a frequency-distribution table of the

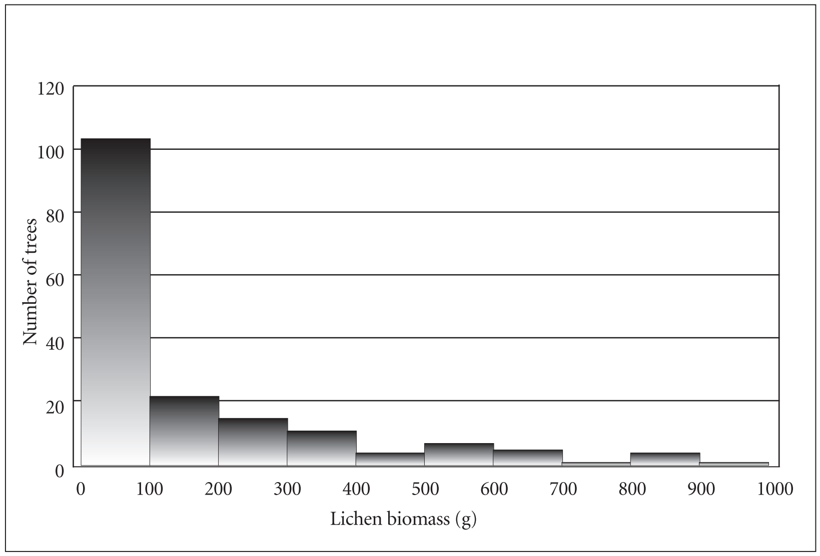


figure 4 *Frequency distribution of* Alectoria *and* Bryoria *biomass in the lower canopy of trees in an ESSF stand.*

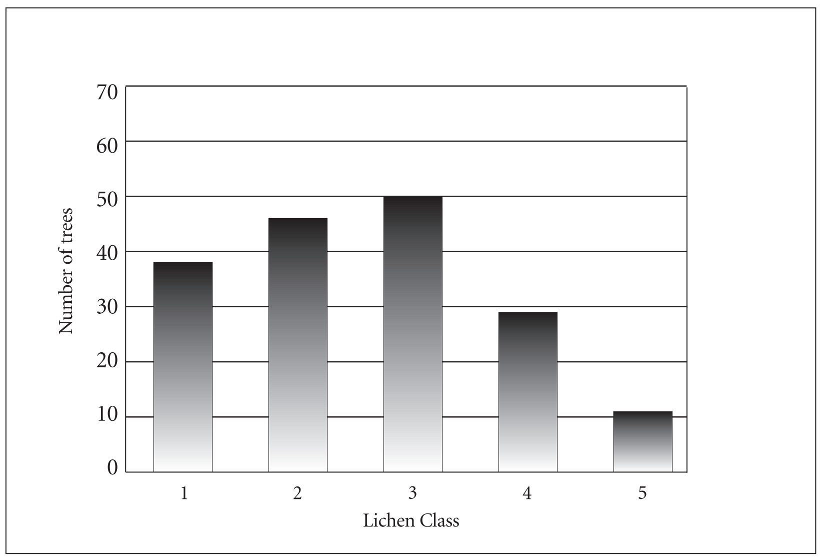


figure 5 *Frequency distribution of Lichen Class scores, based on the same dataset as Figure 4.*

6 The relationship between scores and biomass is described in Section 6.

A frequency-distribution table is a better summary of lichen data than the mean score.

following type, here representing two hypothetical sites to be compared:

	Lichen Class scores						
	0	1	2	3	4	5	Total
Site 1 no. of trees:	1	13	23	31	19	1	88
Site 2 no. of trees:	0	11	20	29	20	2	82

Bar graphs based on frequency distributions are useful tools for assessing whether sites are similar or different, and whether they have high or low levels of lichen abundance. Figure 6 shows the frequency distribution of Lichen Classes at two sites used regularly by mountain caribou in winter. The frequencies are plotted as percentages of each sample.[7] Both sites have a high proportion of trees in the classes thought to be useful to caribou—67% of scores ≥ 3 at Site 1 and 57% at Site 2. In contrast, Figure 7 shows the frequency distribution of Lichen Classes at two ESSF sites that have low lichen abundance and are not used as winter range by mountain caribou. Only 7 and 9% of the two samples, respectively, have lichen scores of Class 3 or higher.

Although graphing the data is often enough for basic comparisons such as these, the differences may not always be as distinct as between Figures 6 and 7, or the sample sizes may be small, raising the possibility that the result is due to chance. Then, a statistical test may be required, as discussed in Section 5.

All the information needed for formal tests on score-distributions is contained in the frequency table. However, the user may also wish to assess how scores are distributed over different parts of the site, or how much lichen is present per unit area. For these purposes

figure 6 *Lichen score-frequencies (trees > 7.5 cm dbh) at two sites used as mountain caribou winter range.*

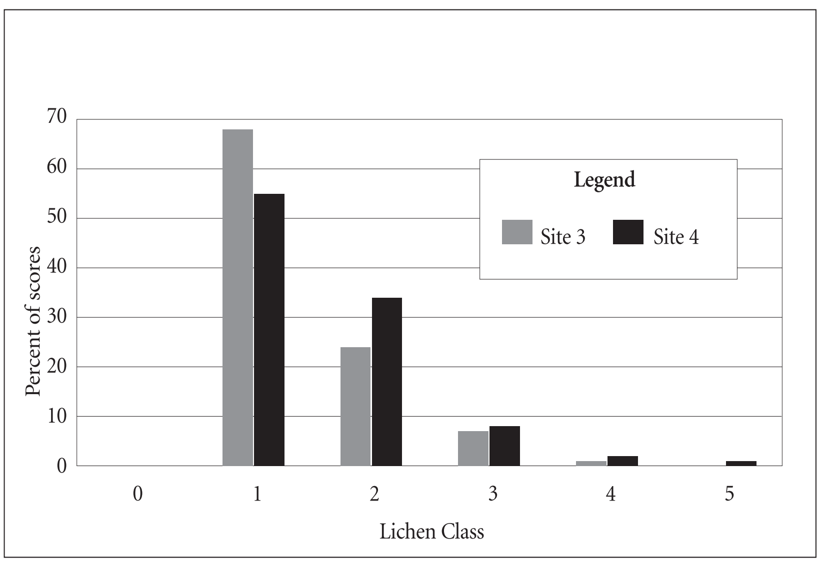


figure 7 *Lichen score-frequencies (trees > 7.5 cm dbh) at two sites not used as mountain caribou winter range.*

7 When sample sizes differ, as at these sites, the score-counts should be plotted as percentages. When compared by statistical methods (described in Section 5), the counts themselves are used; unequal sample sizes are automatically taken into account.

further information is required. To examine spatial variation, it is necessary to record the location of each score. To estimate total amounts of lichen, conversion factors are required (Section 5) to express the scores as biomass equivalents. Biomass equivalents are especially useful for planning and evaluating harvesting prescriptions at the block level.

Often, bar graphs are all that is needed to tell whether sites are similar or different in lichen abundance.

5 USING THE FIELD GUIDE FOR RECONNAISSANCE

Reconnaissance objectives for lichen assessment

Lichen assessments at the reconnaissance level are usually made for one or all of the following objectives:

- to classify areas into broad categories of lichen abundance
- to identify and roughly map discontinuities in lichen abundance
- to determine the dominant lichen genus in an area (e.g., mainly *Alectoria*, mixed *Alectoria* and *Bryoria*, or mainly *Bryoria*)

For operational reconnaissance purposes, the Field Guide will normally be used in areas where site conditions make stands suitable as winter range for caribou. In addition to lichen abundance, two of the most important site conditions affecting caribou use are:

- Slope and topography. Caribou use areas with moderate topography more than areas with rugged topography. They use slopes <45% more than steeper slopes.

- Stand structure. Caribou seem to prefer stands open enough so they can see around them. This may be one reason they avoid dense young stands.

The following recommendations also apply to sampling for other purposes, such as management planning at the stand or block level (Section 6), and research or inventory (Section 8).

Sampling methods

Various sampling methods can be used at the reconnaissance level. Some methods that have given comparable results are:

- plots at intervals along line transects
- selectively located plots within strata predetermined for other purposes
- plots at regular spacings on a grid
- line or belt transects in which every tree on the transect is sampled

From the information available to date, it is not possible to say that any of these methods is better than the others for surveying lichen abundance. In choosing among them, the major considerations will usually be the objectives of the survey, the size and shape of the area, and the compatibility with methods used to gather other data at the same time (e.g., timber cruising). Commonly, lichen assessments will be fitted into a sampling protocol already developed for another purpose.

Defining the sampling domain

Whatever method is chosen, the first step in a sampling plan is to define the *sampling domain* (also termed the sampling *frame* or sampling *stratum*). This is the population of trees from which the sample will be taken. Most often, the domain will be all trees >7.5 cm diameter at breast height (dbh) in some defined area, such as a portion of caribou range, or a particular forest stand, or a proposed cutblock within it.

However, the area might consist of distinctly different parts, in which lichens might be more abundant in some than in others; or the aim of the survey might be to compare different tree species, sizes, or ages within the same area. Each such category is a separate domain requiring an adequate sample size, even if the samples for each are collected simultaneously.

Determining the sample size

Once the sampling domain has been defined, the next step is to determine the number of trees to be scored within it. This is set by the desired level of assurance that the sample scores will reflect the scores on all the trees present.

The minimum sample recommended is 150 trees per domain. This will provide 95% assurance that the sample frequency for each score will differ by no more than 10% from its true frequency in the domain as a whole.[8]

If plots are used, aim for five to 10 trees in each plot. Fewer than five trees is too few to encompass the typical variation in a stand, and more than 10 trees seldom adds much further variation. Circular plots of 0.01 ha (radius 5.64 m) will usually be adequate for stands with about 600 stems/ha or more. In stands with 300–600 stems/ha, 0.015-ha plots (radius 9.91 m) increase the likelihood of obtaining the minimum five trees.

At an average of five trees per plot, about 30 plots will be required to obtain 150 trees in total. Evidence from existing datasets has shown that the variation from plot to plot will usually stabilize once 25–30 plots have been sampled, as long as the area as a whole is relatively uniform (i.e., no obvious patchiness in lichen abundance or occurrence). If abundance varies widely from place to place, the area should be sub-divided into more homogeneous portions and 30 plots taken from each portion.

8 If a sample of fewer than 150 trees has already been scored, its reliability can be assessed by calculating the 95% confidence limits (CL) of each score-frequency. If the lower CL for any frequency is zero, or the upper CL is more than 10% greater than the frequency itself, additional trees should be scored or a new and larger sample taken.

Laying out the sample

To provide unbiased results, any tree sampled must have the same chance of being chosen as any other, even though the 150 trees may be just a small minority of the total trees present. The sample must therefore span the whole of the survey area, and the sampling points should be randomly placed, regardless of whether a line transect or a two-dimensional array of plots is used.

Transects for reconnaissance purposes

Transects are an effective way to conduct the first reconnaissance of a site. No time is lost in setting up an array of plots, and data are collected continuously while the area is being traversed. Findings from the initial survey can show whether a more intensive or more local survey would be worthwhile, and whether the area should be divided into strata to be sampled separately. [9]

Transects are also well suited for sampling lichens along an environmental gradient, such as elevation or moisture regime. Except to sample a gradient, however, the user must ensure that the transect route does not follow some geographic feature that might affect the amount of lichen present. Roads or stand edges are obvious examples, but samples obtained along wildlife trails may also be misleading because the trails seldom run through typical parts of the site.

Unless the area is rather small, the minimum 150 trees may be obtained long before the area has been traversed. Transects through a large area should therefore be sampled at intervals, rather than scoring every tree encountered on the line. One way to do this would be to determine the total length of the path to be traversed, select 30 distances along the transect at random, and place a plot at each predetermined location as the transect is walked (Figure 8).

Local sampling or smaller sites

When time or distance to be traversed is not the primary concern, a two-dimensional grid may be more suitable. A grid layout is more likely to spread the sample over all portions of the site, and is easier to stratify if needed. Map the site with grid-lines 10 m apart, and place a plot at each of 30 randomly chosen intersections (30 per stratum if the site is being split into sub-units).

Use fixed-area plots, not prism plots

Lichen score-frequencies obtained from fixed-area plots require no adjustment for tree size (dbh). However, prism plots select more large trees than small trees, and large trees often have more lichen. Prism plots should not be used for sampling lichen unless they are part of a cruise that will be corrected for bias in tree selection.

If prism plots are used, the data must be corrected for differences in the probability of sampling trees of different sizes.

9 Stratification is discussed further in Section 8.

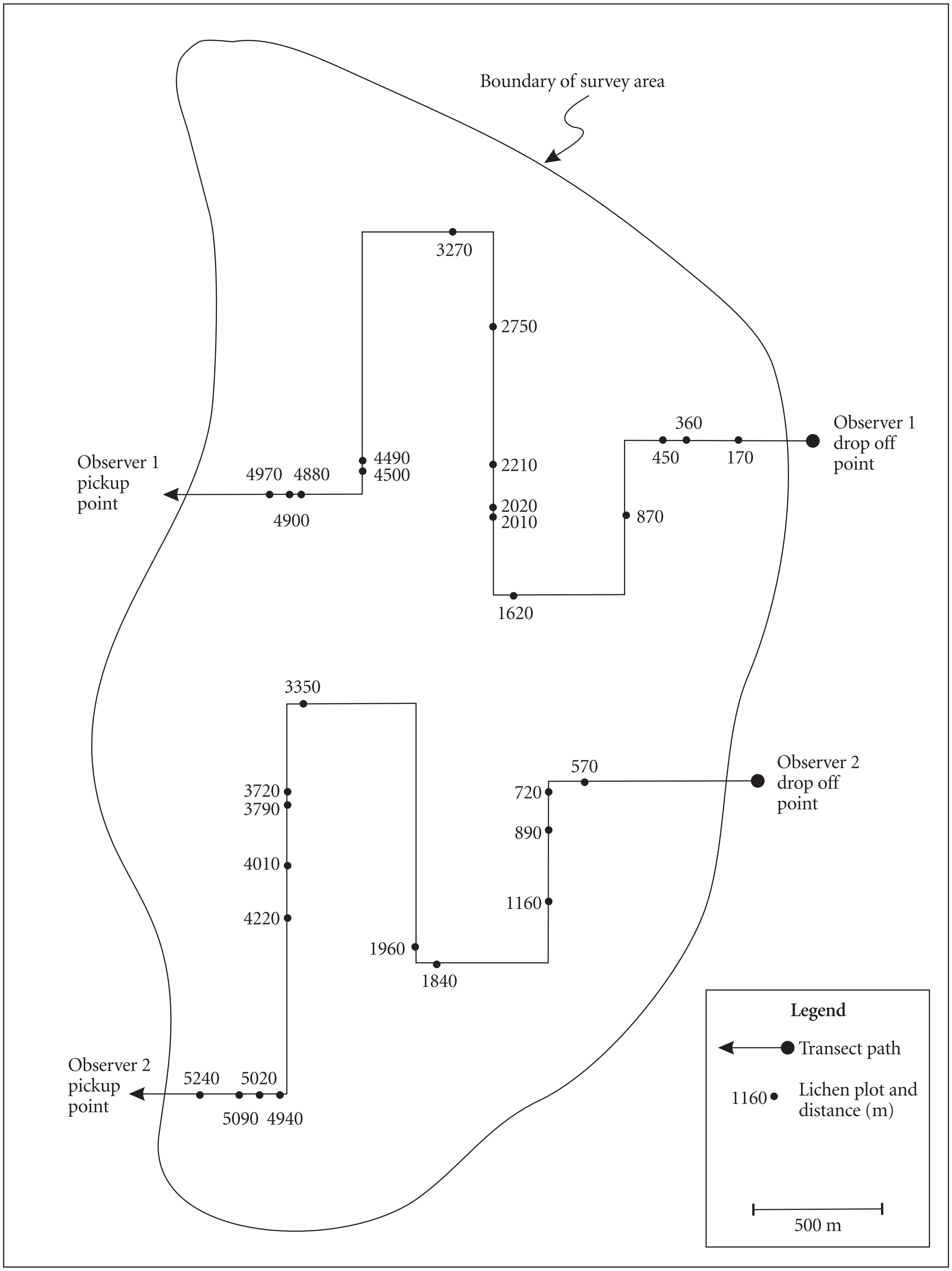


figure 8 *Lichen plots at random distances along two transect paths planned to cover a mountainside survey area of about 1000 ha.*

Set the minimum diameter of sample trees at 7.5 cm dbh
Usually, the minimum diameter limits used in forestry surveys are also suitable for lichen surveys. However, some types of vegetation survey may include very small trees in the sample. Since very small trees usually have low lichen abundance, including them can result in inflated frequencies in the lower Lichen Classes. A minimum diameter of at least 7.5 cm is suggested for sample trees in lichen surveys.

Compiling the data

A spreadsheet with a count-frequency accumulator and graphing capabilities will be sufficient to handle all of the tasks described below.

Determine the frequency distribution of lichen scores
For each area or stratum sampled, determine the total number of stems in each Lichen Class and produce a frequency table (Table 1). Table the frequencies according to any categories that will be important in your analysis, such as tree species or lichen genus composition.

Show the sample size
Include the plot size and the number of plots or transects per stratum (Table 1). The plot size is needed if lichen scores are to be expressed per unit area, or compared with stem densities.

Stem density can be calculated for each Lichen Class per stratum by dividing the total number of scores in each class by the combined area of the sample plots in that stratum.

A compilation that includes the frequency distribution and the sample size (number of plots and plot size) retains all the basic information in the sample.

table 1 *Frequency distribution of Lichen Class scores, with associated information. A= >70%* Alectoria*; AB= mixed* Alectoria *and* Bryoria*; B= >70%* Bryoria*. Genus composition is not recorded for Lichen Class 1 trees.*

		Lichen Class					
		0	1	2	3	4	5
Tree species							
	Subalpine fir	0	17	37	76	27	2
	Spruce	0	3	13	20	9	0
	Snags	0	5	5	14	2	0
	Total no. of scores	0	25	55	110	38	2
Genus composition							
	A	—	—	16	37	15	0
	AB	—	—	35	71	23	2
	B	—	—	4	2	0	0
	Total no. of scores	—	—	55	110	38	2
Stems/ha		0	83	183	367	127	7
		Total plots:	30		Plot size (ha):	0.01	

Analyzing the data

Lichen abundance can be assessed for a site, or compared among sites, or compared among strata by:

- the differences in the relative frequencies of different scores
- the differences in the percentage of scores above a certain limit
- the cumulative score-total(s) or biomass total(s) for the site(s) or categories
- the total or average biomass per plot

These are not the only possibilities. However, the first step in any of these analyses should be to produce bar graphs showing the number of scores per Lichen Class, for each category of interest. Bar graphs quickly indicate the main features of each sample, such as the most common score, how typical it is for the sample as a whole, and how it compares to the most common score in other samples.

If these features are distinct and the sample sizes are adequate, a graph will often be enough to answer the basic question of interest; for example, whether two sites differ in lichen abundance. But if the samples are small or the difference between them does not appear distinct, a more formal statistical test may be required.

The common purpose of the statistical tests described below is to gauge the likelihood that the results observed could have occurred by chance instead of representing a real biological effect. The calculations required are not complex. A spreadsheet is sufficient for handling them, and procedures can be found in most statistical texts.[10]

Comparing relative differences in lichen abundance

To find out whether the number of scores differs significantly among Lichen Classes, their relative frequencies can be compared. This can be done for a single sample (comparing class with class) or for two or more samples (comparing all classes jointly).

If the data are compiled as raw frequencies with no further conversion (as in Table 1), they should be regarded as samples from a multinomial distribution, and analyzed using methods for dealing with proportions or counts. "Contingency" methods (chi-square or log-likelihood ratio G) are traditional ways for doing this.

Frequency distributions should be analyzed by methods designed for proportions or counts.

10 Various pre-programmed routines (e.g., SYSTAT®, SPSS®, and SAS®) further reduce the task by generating probability levels internally, thus avoiding the need to refer to probability tables.

For assessing a single set of scores, a “one-way” chi-square or *G*-test can show the level of probability that the score-frequencies differ non-randomly from Class to Class. The confidence limits of each frequency (see footnote 8, Section 5) can show which particular frequencies differ significantly from each other (e.g., the number of Lichen Class 3s versus the number of Class 2s). If one or more frequency is near zero (as is often the case with Score 4s or 5s) the confidence limits will indicate whether it differs from zero by more than random chance.

For comparing two sets of scores, a “two-way” chi-square or *G*-test can be used. Typically this would be to compare two sites. Either test can also be used for comparing a single set of scores with a pre-defined “target” distribution. An example might be to compare observed scores with a desired distribution of scores, such as from a stand management prescription (see Section 6).

Chi-square tests are familiar and easy to use. *G*-tests are less common but just as easy to calculate. Both tests can also be applied to summarized data, such as the number of high or low scores, if the full array of scores is unavailable. The chi-square method has an important limitation, however. Small score-frequencies at the upper or lower tail of the distribution may distort the X^2 statistic and give unreliable results. When one or more frequencies is <5, the usual advice is to combine them with the next adjoining class (e.g., Lichen Class 1 with Class 2, or Class 5 with Class 4). However, the number of high or low scores may be the factor that differs most between one sample and another, and if score classes are combined, this information is lost.

The *G*-test is considered more robust to this limitation than the chi-square test. For a *G*-test, frequencies <5 do not need to be combined, especially if *G* is adjusted as *G*/q.[11] For this reason, the *G*-test is the better choice.

The most powerful test for use with either one or two score-frequency distributions is the Kolmogorov-Smirnov (K-S) test. For a K-S test, unlike chi-square, small frequencies at the tails do not have to be combined—indeed, it is disadvantageous to do so—since the K-S test is sensitive to any difference in asymmetry of samples that are similar in other respects.

Unfortunately, K-S tests are restricted to just one sample or two, but chi-square and *G*-tests can easily be extended to three or more. For the chi-square test, however, the limitation at small scores still applies. Thus, for comparing three or more frequency distributions simultaneously, the recommended method is the log-likelihood ratio, *G*.

Differences in stem density

The tests described above compare only the relative numbers of scores in each Lichen Class. Thus, a *G* or K-S test will show no difference between sites with the same ratios of scores, even if one of the sites has a much larger total number of scores than the other.

11 Sokal, R.R. and Rohlf, J.F. 1995. *Biometry.* Freeman & Company, New York, N.Y. The factor *q* is defined in this reference.

Sites with similar score-ratios might differ in score-totals for either of the following reasons:

- more plots were sampled at one site than the other; or
- the two sites differed in stem density.

In comparing score-ratios, the number of plots is immaterial except to determine the sample size for a *G* or K-S test. However, a difference in stem density would mean a difference in the amount of lichen per unit area, even if each site has the same amount of lichen per tree.

Thus, when samples differ in total number of scores, they should be examined for possible differences in stem density. Since each score represents one tree, stem density is simply the number of scores recorded per plot divided by plot size. If plot size is the same at each site, it can be ignored and the comparison can be based directly on the number of scores, plot by plot. Two tests suitable for comparing stem densities between different samples are:

- Kruskal-Wallis ANOVA (Analysis of Variance) for two or more independent samples (e.g., samples from different sites)
- Friedman ANOVA for related samples (e.g., samples from the same site before and after a management treatment)

The Kruskal-Wallis test and the Friedman test have a similar rationale, and are performed on the ranks of the lichen estimates, rather than the estimates themselves.

Comparing absolute differences in lichen abundance

There may be situations in which users wish to calculate lichen abundance on an absolute basis. Lichen abundance expressed as biomass per unit area integrates the effects of lichen abundance and stem density into a single measure. Expressions of biomass per unit area make it easy to compare overall lichen abundance between sites, but not to determine whether differences are due to lichen scores, stem density, or both.

To compare lichen abundance per unit area between sites, convert the score-value for each tree to its biomass equivalent, using the conversion factors given in Section 6. Using these values, calculate the total lichen biomass for each plot. The outcome may look like a dataset with an infinite range of possible values that could be analyzed using parametric ANOVA or Student's-*t* test. The appearance of continuity is misleading, however, since each score-class spans a range of lichen abundance but has only a single biomass conversion factor. The range of possible values in any one sample is restricted rather than infinite, and its distribution is disjunct rather than continuous. Therefore, lichen data expressed in biomass equivalents are best analyzed by non-parametric methods. The Kruskal-Wallis test for independent samples and the Friedman test for related samples are suitable non-parametric tests for comparing lichen biomass at the plot level.

Lichen scores expressed as biomass do not meet the assumptions of parametric statistics, and should be analyzed using non-parametric methods.

A remark on the use of statistical tests

Statistical tests are a helpful analytical tool, but final judgement rests with the user, not on the test alone. Other considerations should be taken into account. For example, perhaps the samples are small, but do they differ distinctly nonetheless, as in Figures 6 and 7? How big is the risk that the difference is due to chance? By convention in statistical tests, a risk greater than 5% (i.e., $p > .05$) is considered "high". But if the risk is only 6 or 7%, or even 10%, a greater likelihood still exists that the difference is genuine. Lastly, differences at the higher Lichen Classes may be biologically significant even if not statistically significant, and they may also differ spatially even if not in other respects. The internal structure of the samples should not be ignored.

Mapping the data

Lichen score-frequencies often vary between different parts of a site. When this is suspected, the data should be mapped and examined for signs of clustering. A multiple frequency distribution cannot feasibly be mapped, and so some form of data reduction or summarization is needed. The percentage of trees per plot with Lichen Class scores ≥ 3, or the number per ha or km^2, are mappable attributes. A threshold Lichen Class of 3 is suggested because of evidence that caribou are more likely to perceive trees of Lichen Class 3 or greater as a food source (Section 3). Since these counts or percentages focus on the upper end of the abundance scale, they are more biologically meaningful than averages based on the whole scale (i.e., including low-scoring trees that caribou ignore). Figure 9 shows how mapped lichen scores could be used to stratify a heterogeneous survey area into two lichen-abundance zones.

Using the data to manage caribou habitat

At present, not enough information is available on patterns of lichen abundance in caribou range to specify how much lichen must be present for a stand to be useful as winter foraging habitat. Current research will help to address this question. In addition, users who collect lichen abundance data operationally in areas of known caribou habitat can help by registering their projects in a central data registry and contributing data to the information base if asked to do so. A data registration form can be found at the back of this handbook.

Where site conditions (slope, topography, and stand structure) are suitable for caribou winter range, lichen abundance data can be used to rank stands for importance as potential foraging areas for caribou. This information can be used to guide decisions about whether a particular stand should be harvested, and what silvicultural systems should be considered.

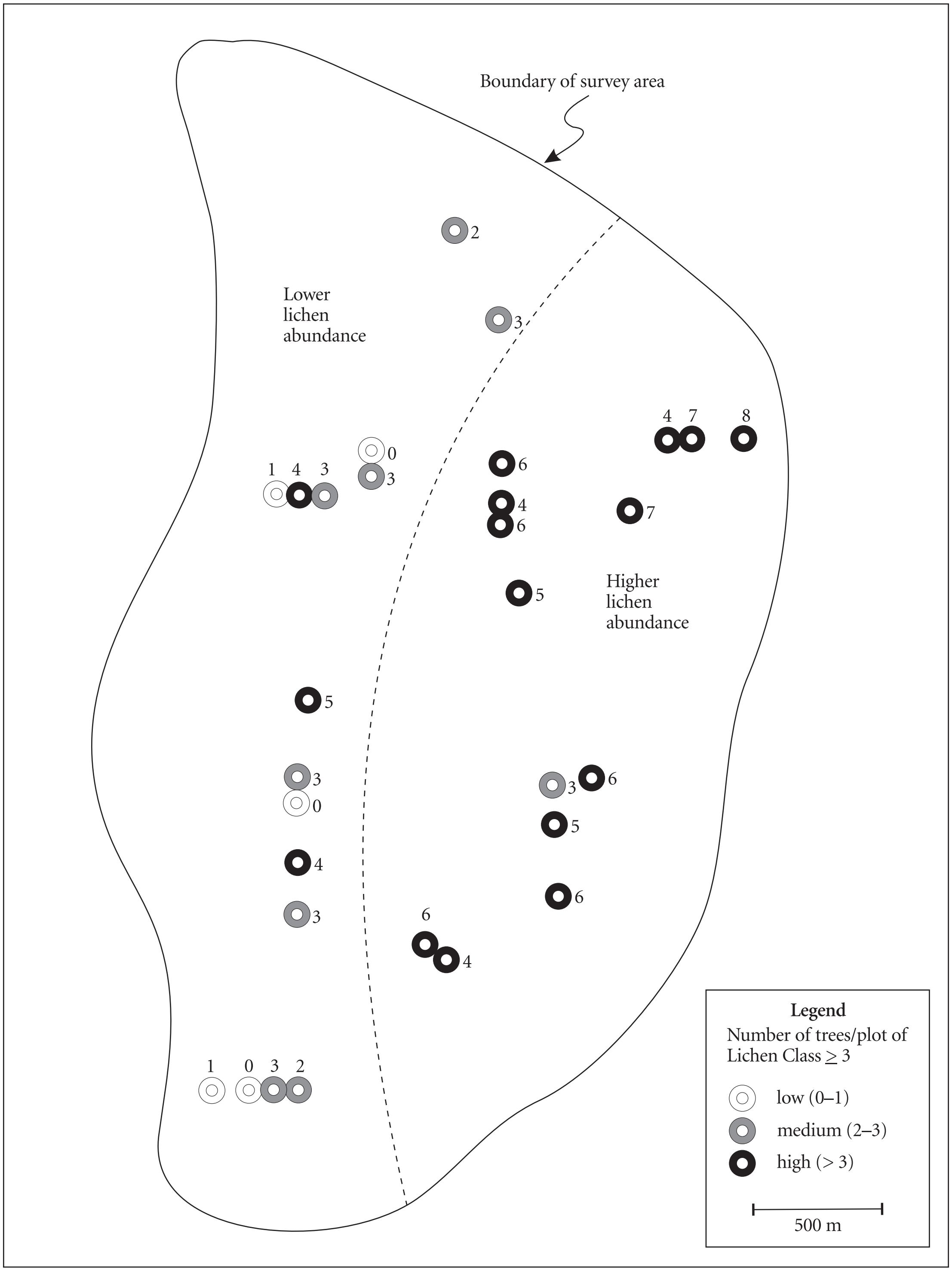


figure 9 *Lichen abundance zones based on the distribution of lichen plot scores in the survey area shown in Figure 8.*

Lichen abundance is only one factor that affects how caribou use an area in winter, and it is only one factor to consider in planning forest management. Some of the other factors that affect caribou use are:

- Access. Road access into caribou ranges can make caribou more vulnerable to legal and illegal hunting and can increase the likelihood of disturbance. Ploughed roads or packed trails can increase access by wolves at times when the snowpack is soft.
- Disturbance. Caribou have abandoned some winter ranges that became heavily used by snowmobilers. Heli-skiing and cross-country skiing may also be significant disturbance factors.
- Predation risk. The strategies of spacing themselves out over large areas, using different winter ranges in different years, and moving extensively within ranges in a single winter, probably help caribou avoid predation. Caribou may avoid using ranges where the risk of predation is high.
- Habitat fragmentation. Parts of some ranges may not be used because they have become isolated from other parts, or because the amount of suitable habitat has shrunk.

Forest management in caribou habitat should be planned so that large areas are in a suitable condition for use by caribou, and are free from roads and (if possible) snowmobile access. Abundant arboreal lichens do not in themselves make an area suitable habitat, but without them an area cannot be used as winter range by mountain caribou.

6 USING THE FIELD GUIDE FOR PLANNING AT THE BLOCK LEVEL

Block-level objectives for lichen assessment

Usually, the purpose of lichen assessment at the block level is to provide the information needed to select a silvicultural system and to plan a prescription. Some of the objectives might be:

- To quantify overall lichen biomass in the block. Overall lichen abundance is an indicator of the importance of the stand as potential winter range for caribou.
- To identify and map discontinuities in lichen abundance. Information on the spatial patterning of lichen abundance and of genus composition can be used to plan harvest block locations and boundaries.
- To identify the dominant lichen genus, and map discontinuities in genus composition if they exist. *Alectoria* and *Bryoria* differ in their ecological tolerances, and are likely to respond somewhat differently to treatments that open the canopy.

- **To determine the contribution of dead trees to lichen abundance.** If dead trees are an important substrate for available lichen in the stand, then a harvesting method should be selected that will permit retention of some of those trees without endangering workers.
- **To relate lichen abundance to tree species and diameter.** A table that relates lichen abundance to tree species and diameter can be used to predict the effects of various possible selection harvesting prescriptions on lichen abundance in the residual stand.

Sampling methods

Lichen assessments at the block level are best done in conjunction with a timber cruise. Both kinds of data needed for a block-level analysis can then be obtained at the same time and compiled jointly. Lichen scores tend to vary considerably from plot to plot and from tree to tree. Generally, 25–30 plots of 5–10 trees each have been found adequate to characterize a homogeneous area, regardless of size. If a block is heterogeneous in lichen abundance, it should be stratified into sampling units that are more homogeneous within than between, and each stratum should then be sampled separately. More detailed information about sampling methods is found in Section 5.

Prism plots may be used, provided the lichen data are compiled so as to correct for differences in the probability of sampling trees of different sizes, as described below. If the assessments are not being done together with a timber cruise, then **fixed-area plots** are recommended. As at the reconnaissance level, 0.01-ha (radius 5.64 m) plots are recommended for stands with more than 600 stems/ha, and 0.015-ha (radius 9.91 m) plots for stands with 300–600 stems/ha.

The cruise tally sheet does not provide a column for Lichen Classes. The Ministry of Forests recommends that the scores be recorded in Column 60. However, because the numbers 1–7 have already been assigned to another use in that column, alphabetic codes should be substituted for Lichen Class numeric codes as follows:

Lichen Class	Enter in Column 60
0	A
1	B
2	C
3	D
4	E
5	F

This substitution will ensure that there is no confusion with other codes, which could affect appraisal values. **The use of Lichen Class codes in Column 60 should be noted under "Remarks."**

Creating stand tables

The easiest way to compile lichen data for a stand-level analysis is through a special run of the provincial cruise compilation program. At present, the provincial program has not been modified to accommodate lichen data. However, the changes needed are minor, and some forestry consultants have already made them. They generate a stand table that shows the number of stems per hectare in each Lichen Class, by diameter class. Separate tables may be produced for different tree species and different timber types, or for other strata within the block. The tables should be compiled in a general format, such as ASCII text, so they can be easily exported to a spreadsheet and re-formatted as required for further analysis. Tables 2 and 3 are examples of stand tables by Lichen Class for a proposed block with two tree species.

WARNING Other codes used in Column 60 of the cruise tally sheet affect the appraisal value of the stand. Users must ensure that compilations that include lichen codes do not improperly affect appraisal values.

table 2 *Stand table for subalpine fir by Lichen Class*

	Subalpine fir trees per hectare					
dbh class	Lichen Class 1	Lichen Class 2	Lichen Class 3	Lichen Class 4	Lichen Class 5	Total
10	49.5	70.1	20.9	—	—	140.5
15	5.1	30.4	60.8	5.1	—	101.4
20	—	10.3	61.6	10.3	—	82.2
25	—	5.9	26.6	14.8	3.0	50.3
30	—	—	37.4	9.4	—	46.8
35	—	5.5	13.8	8.3	2.0	29.6
40	—	—	10.0	20.0	—	30.0
45	—	—	16.3	8.1	—	24.4
50	2.5	—	—	10.1	—	12.6
55	—	1.5	3.0	3.0	—	7.5
60	—	—	1.1	—	—	1.1
65	—	—	2.0	—	—	2.0
70	—	—	—	—	—	0.0
Live trees/ha	57.1	123.7	253.5	89.1	5.0	528.4
Snags/ha	8.2	16.4	46.5	8.2	—	79.3

table 3 *Stand table for spruce by Lichen Class*

dbh class	Spruce trees per hectare					
	Lichen Class 1	Lichen Class 2	Lichen Class 3	Lichen Class 4	Lichen Class 5	Total
10	—	8.2	—	—	—	8.2
15	5.5	5.5	—	—	—	11.0
20	—	17.7	8.8	—	—	26.5
25	—	5.3	10.6	—	—	15.9
30	—	0.9	1.8	1.8	—	4.5
35	—	—	6.1	12.2	—	18.3
40	—	5.1	10.2	5.1	—	20.4
45	—	—	5.9	5.9	—	11.8
50	2.1	—	6.3	4.2	—	12.6
55	—	—	7.6	—	—	7.6
60	—	—	5.7	—	—	5.7
65	—	—	1.9	—	1.9	3.8
70	—	—	—	1.3	—	1.3
75	—	—	0.7	—	—	0.7
80	—	0.3	—	—	—	0.3
Live trees/ha	7.6	43	65.6	30.5	1.9	148.6
Snags/ha	7.1	—	—	—	—	7.1

Calculating lichen biomass from stand tables

To produce a lichen biomass table, arrange the Lichen Class data by tree species and diameter class. The approximate biomass midpoints of the Lichen Classes provide an estimate of the amount of lichen (in grams) on a tree in a given Lichen Class. Biomass midpoints are used as multiplier factors to calculate the amount of lichen contributed by the trees in a diameter class. The Lichen Class conversion factors are:

Lichen Class	Multiplier
1	2.5
2	25
3	150
4	450
5	800

As Lichen Class 5 has no midpoint, 800 is suggested as a multiplier. It bears the same proportional relationship to the Class 4/5 boundary as the Class 4 midpoint does to the Class 3/4 boundary.

Table 4 is a lichen biomass table based on the data in Tables 2 and 3. A species summary (Table 5) shows the contribution of each tree species and of dead trees to the overall lichen biomass in the proposed block.

Be aware that the biomass values produced in this way are only estimates. Scoring may not always be done consistently, and even if it is, the Lichen Classes are very broad at the upper end of the scale. However, biomass estimates are valuable for developing and comparing timber harvesting prescriptions that attempt to reduce the impact on lichen abundance in the stand.

table 4 *Lichen biomass summary for subalpine fir (B) and spruce (S) based on Tables 2 and 3*

dbh class	Lichen Class 1 B s/ha*	Lichen Class 1 S s/ha*	Lichen Class 1 Total s/ha*	Lichen Class 1 Total g/ha	Lichen Class 2 B s/ha*	Lichen Class 2 S s/ha*	Lichen Class 2 Total s/ha*	Lichen Class 2 Total g/ha	Lichen Class 3 B s/ha*	Lichen Class 3 S s/ha*	Lichen Class 3 Total s/ha*	Lichen Class 3 Total g/ha	Lichen Class 4 B s/ha*	Lichen Class 4 S s/ha*	Lichen Class 4 Total s/ha*	Lichen Class 4 Total g/ha	Lichen Class 5 B s/ha*	Lichen Class 5 S s/ha*	Lichen Class 5 Total s/ha*	Lichen Class 5 Total g/ha	All Lichen Classes Total g/ha	All Lichen Classes Total s/ha*
10	49.5	0.0	49.5	123.8	70.1	8.2	78.3	1,957.5	20.9	0.0	20.9	3,135.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5,216.3	148.7
15	5.1	5.5	10.6	26.5	30.4	5.5	35.9	897.5	60.8	0.0	60.8	9,120.0	5.1	0.0	5.1	2,295.0	0.0	0.0	0.0	0.0	12,339.0	112.4
20	0.0	0.0	0.0	0.0	10.3	17.7	28.0	700.0	61.6	8.8	70.4	10,560.0	10.3	0.0	10.3	4,635.0	0.0	0.0	0.0	0.0	15,895.0	108.7
25	0.0	0.0	0.0	0.0	5.9	5.3	11.2	280.0	26.6	10.6	37.2	5,580.0	14.8	0.0	14.8	6,660.0	3.0	0.0	3.0	2,400.0	14,920.0	66.2
30	0.0	0.0	0.0	0.0	0.0	0.9	0.9	22.5	37.4	1.8	39.2	5,880.0	9.4	1.8	11.2	5,040.0	0.0	0.0	0.0	0.0	10,942.5	51.3
35	0.0	0.0	0.0	0.0	5.5	0.0	5.5	137.5	13.8	6.1	19.9	2,985.0	8.3	12.2	20.5	9,225.0	2.0	0.0	2.0	1,600.0	13,947.5	47.9
40	0.0	0.0	0.0	0.0	0.0	5.1	5.1	127.5	10.0	10.2	20.2	3,030.0	20.0	5.1	25.1	11,295.0	0.0	0.0	0.0	0.0	14,452.5	50.4
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.3	5.9	22.2	3,330.0	8.1	5.9	14.0	6,300.0	0.0	0.0	0.0	0.0	9,630.0	36.2
50	2.5	2.1	4.6	11.5	0.0	0.0	0.0	0.0	0.0	6.3	6.3	945.0	10.1	4.2	14.3	6,435.0	0.0	0.0	0.0	0.0	7,391.5	25.2
55	0.0	0.0	0.0	0.0	1.5	0.0	1.5	37.5	3.0	7.6	10.6	1,590.0	3.0	0.0	3.0	1,350.0	0.0	0.0	0.0	0.0	2,977.5	15.1
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	5.7	6.8	1,020.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,020.0	6.8
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.9	3.9	585.0	0.0	0.0	0.0	0.0	0.0	1.9	1.9	1,520.0	2,105.0	5.8
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	585.0	0.0	0.0	0.0	0.0	585.0	1.3
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	105.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.0	0.7
80	0.0	0.0	0.0	0.0	0.0	0.3	0.3	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.3
Total	57.1	7.6	64.7	161.8	123.7	43.0	166.7	4,167.5	253.5	65.6	319.1	47,865.0	89.1	30.5	119.6	53,820.0	5.0	1.9	6.9	5,520.0	111,534.3	677.0

* stems/ha

Lichen Class	Multiplier
1	2.5
2	25
3	150
4	450
5	800

table 5 *Pre-harvest summary by species based on Tables 2, 3, and 4**

Lichen Class		Subalpine fir	Spruce	Snags	Total
1	stems	57	8	15	80
	grams	143	19	38	200
2	stems	124	43	16	183
	grams	3,093	1,075	410	4,578
3	stems	254	66	47	367
	grams	38,025	9,840	6,975	54,840
4	stems	89	31	8	128
	grams	40,095	13,725	3,690	57,510
5	stems	5	2	0	7
	grams	4,000	1,520	0	5,520
Total grams/ha		85,355	26,179	11,113	122,647
% grams		70	21	9	100
Total stems/ha		528	149	86	763

* Values may not sum to totals because of rounding

Frequency distributions

For comparison with other stands, frequency distributions of lichen classes may be graphed using the information in the stand tables (Figure 10).

Producing a map

Mapped results of lichen surveys may be useful for a variety of purposes within blocks, such as identifying different treatment units, laying out group selection openings, or locating wildlife tree patches or other long-term retention areas. Figure 11 is a block map showing the number of trees in each 0.01-ha plot with Lichen Class 3 or greater, and how that information could be used to locate openings that will maximize the retention of lichen forage after the first harvest entry. Of course, targeting areas of low lichen abundance for harvest openings is not always appropriate. That will depend on the long-term management objectives, and the reasons for low lichen abundance in certain portions of the block.

Planning the prescription

Many factors affect the development of a silviculture prescription in caribou habitat. Some of these are:

- higher-level plan direction
- economic considerations
- pre-harvest stand structure
- ecological requirements of desired tree species
- terrain and soil conditions
- windthrow hazard
- forest health concerns
- abundance and distribution of lichens in the stand
- contribution of dead trees to lichen abundance

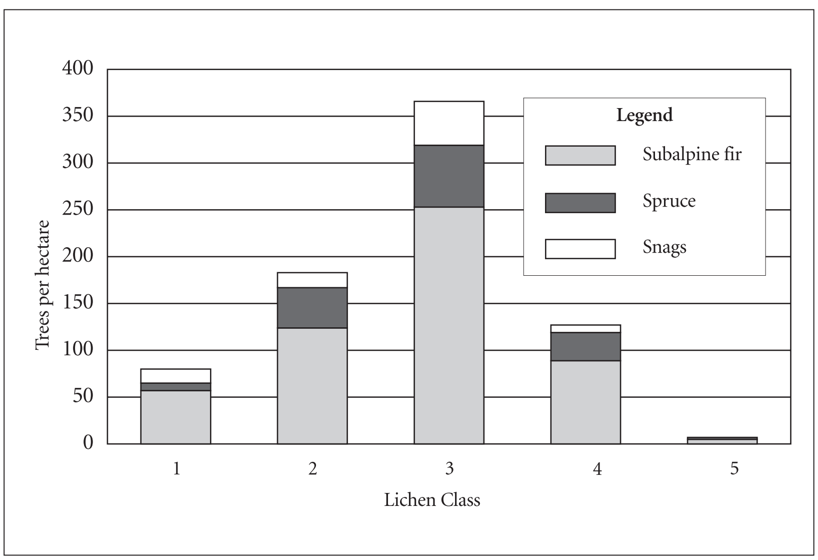


figure 10 *Trees per hectare by Lichen Class based on Tables 2 and 3.*

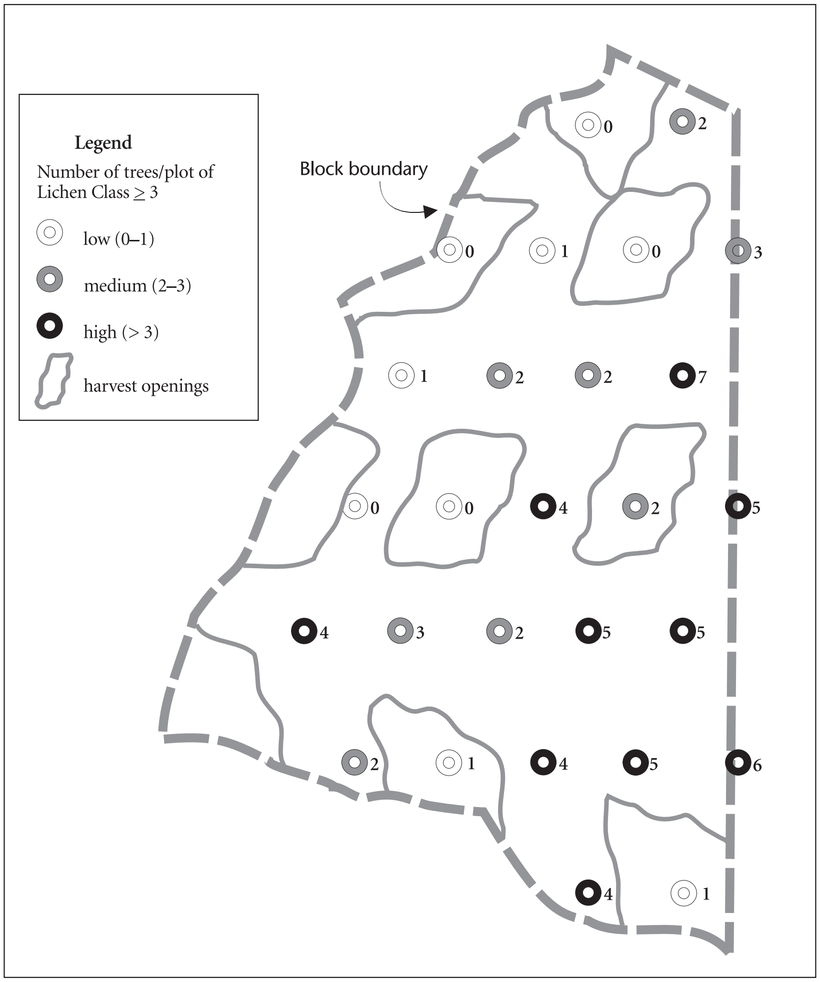


figure 11 *Lichen plot scores in a group selection block, and harvest openings planned to maximize lichen retention after the first harvest entry.*

Prescription planning in mountain caribou habitat is discussed in *Mountain Caribou in Managed Forests: Preliminary Recommendations for Managers.*[12]

Where basal-area selection harvesting is being planned, stand tables can be used to predict the effects of various possible prescriptions. A spreadsheet with linear programming capability is ideal for this. Enter the Lichen Class data, broken down by tree species and diameter class, as in Table 4. Then test various scenarios by varying the number of stems/ha in each species/diameter class, as called for in a potential prescription. In most stands, a prescription that is suitable for caribou habitat should aim at least to preserve the same relative frequency distribution of Lichen Classes that existed before harvesting, while removing no more than 30% of the timber volume. Ideally, if the harvesting can be focused on low-scoring trees, the proportion of trees with high lichen abundance can be increased.

Lichen abundance data can help with:

- **planning locations and boundaries of treatment units**
- **projecting the impacts of potential prescriptions on lichen abundance**
- **planning how dead trees will be managed**

12 Stevenson, S.K., H.M. Armleder, M.J. Jull, D.G. King, E.L. Terry, G.S. Watts, B.N. McLellan, and K.N. Child. 1994. *Mountain Caribou in Managed Forests: Preliminary Recommendations for Managers.* B.C. Ministry of Forests, Victoria, B.C.

table 6 *Lichen biomass summary table for a single-tree selection prescription for subalpine fir (B) and spruce (S), based on Tables 2 and 3*

	Lichen Class 1				Lichen Class 2				Lichen Class 3				Lichen Class 4				Lichen Class 5				All Lichen Classes	
dbh class	B s/ha*	S s/ha*	total s/ha*	total g/ha	B s/ha*	S s/ha*	total s/ha*	total g/ha	B s/ha*	S s/ha*	total s/ha*	total g/ha	B s/ha*	S s/ha*	total s/ha*	total g/ha	B s/ha*	S s/ha*	total s/ha*	total g/ha	total g/ha	total s/ha*
10	49.5	0.0	49.5	123.8	70.1	8.2	78.3	1,957.5	20.9	0.0	20.9	3,135.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5,216.3	148.7
15	5.1	5.5	10.6	26.5	30.4	5.5	35.9	897.5	60.8	0.0	60.8	9,120.0	5.1	0.0	5.1	2,295.0	0.0	0.0	0.0	0.0	12,339.0	112.4
20	0.0	0.0	0.0	0.0	6.9	11.8	18.7	467.5	41.2	5.9	47.1	7,065.0	6.9	0.0	6.9	3,105.0	0.0	0.0	0.0	0.0	10,637.5	72.7
25	0.0	0.0	0.0	0.0	5.0	4.5	9.5	237.5	22.6	9.0	31.6	4,740.0	12.6	0.0	12.6	5,670.0	2.5	0.0	2.5	2,000.0	12,647.5	56.2
30	0.0	0.0	0.0	0.0	0.0	0.8	0.8	20.0	21.6	1.5	23.1	3,465.0	7.9	1.5	9.4	4,230.0	0.0	0.0	0.0	0.0	7,715.0	33.3
35	0.0	0.0	0.0	0.0	3.8	0.0	3.8	95.0	9.5	4.2	13.7	2,055.0	5.7	8.4	14.1	6,345.0	1.4	0.0	1.4	1,120.0	9,615.0	33.0
40	0.0	0.0	0.0	0.0	0.0	2.6	2.6	65.0	5.0	5.2	10.2	1,530.0	10.1	2.6	12.7	5,715.0	0.0	0.0	0.0	0.0	7,310.0	25.5
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	3.2	11.8	1,770.0	4.3	3.2	7.5	3,375.0	0.0	0.0	0.0	0.0	5,145.0	19.3
50	1.5	1.3	2.8	7.0	0.0	0.0	0.0	0.0	0.0	3.8	3.8	570.0	6.1	2.5	8.6	3,870.0	0.0	0.0	0.0	0.0	4,447.0	15.2
55	0.0	0.0	0.0	0.0	1.5	0.0	1.5	37.5	3.0	7.6	10.6	1,590.0	3.0	0.0	3.0	1,350.0	0.0	0.0	0.0	0.0	2,977.5	15.1
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	5.7	6.8	1,020.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,020.0	6.8
65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.9	3.9	585.0	0.0	0.0	0.0	0.0	0.0	1.9	1.9	1,520.0	2,105.0	5.8
70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	585.0	0.0	0.0	0.0	0.0	85.0	1.3
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	105.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.0	0.7
80	0.0	0.0	0.0	0.0	0.0	0.3	0.3	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.3
Total	56.1	6.8	62.9	157.3	117.7	33.7	151.4	3,785.0	196.3	48.7	245.0	36,750.0	61.7	19.5	81.2	36,540.0	3.9	1.9	5.8	4,640.0	81,872.3	546.3

* stems/ha

Lichen Class	Multiplier
1	2.5
2	25
3	150
4	450
5	800

Tables 6 and 7 show the results of a single-tree selection prescription that could be used in the pre-harvest stand described in Tables 2 and 3. In this sample prescription, each diameter class between 17.5 and 52.5 cm in the post-harvest stand has 1.3 times as many stems as the next larger diameter class; stems larger than 52.5 cm dbh are retained. All dead trees are removed. Of the living trees, the Lichen Class distribution of merchantable trees (>17.5 cm) is approximately maintained (Figure 12). In Lichen Class 3 or greater, 332 are retained—75% of the 446 stems/ha in the pre-harvest stand. Overall, the analysis predicts that implementing this prescription would result in 82 kg/ha of arboreal lichen remaining (Table 7), compared to 122 kg/ha in the pre-harvest stand (Table 5).

In this example, only about 9% of the available lichen in the pre-harvest stand occurred on dead trees (Table 5). In some stands, dead trees make a much larger contribution to the lichen forage resource. Where dead trees are an important source of available lichen, managers should consider a prescription that will allow some to be retained. Group selection may offer opportunities to retain dead trees in the leave areas, where they cannot fall into work areas. In some blocks in caribou habitat, the Workers' Compensation Board has granted variances to selectively retain dead trees during harvesting. Any prescription involving retention of dead trees should be developed in consultation with the Workers' Compensation Board, and should ensure that work areas will be safe.

table 7 *Post-harvest summary by species, based on Table 6**

Lichen Class		Subalpine fir	Spruce	Snags	Total
1	stems	56	7	0	63
	grams	140	17	0	157
2	stems	118	34	0	151
	grams	2,943	842	0	3,785
3	stems	196	49	0	245
	grams	29,445	7,305	0	36,750
4	stems	62	20	0	81
	grams	27,765	8,775	0	36,540
5	stems	4	2	0	6
	grams	3,120	1,520	0	4,640
Total grams/ha		63,413	18,460	0	81,872
% grams		77	23	0	100
Total stems/ha		436	111	0	546

* Values may not sum to totals because of rounding

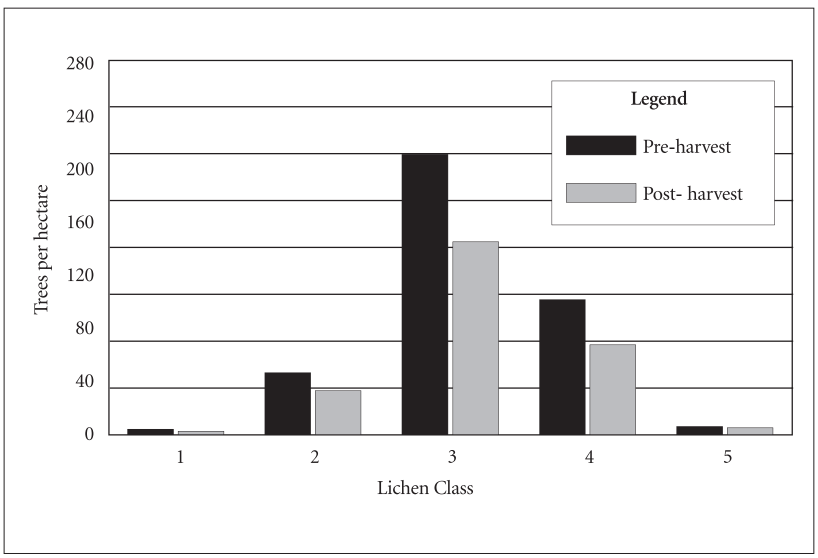


figure 12 *Trees per hectare in Lichen Classes 1–5 before and after a single-tree selection harvest.*

Users can help improve adaptive management in caribou habitat by contributing their data to a central registry, and by monitoring lichen abundance in selection harvesting blocks.

What is adaptive management?

Adaptive management is a structured process for learning from the results of operational activities so that future management can be improved. There is much to be learned about the potential of uneven-aged silviculture systems to maintain caribou habitat. Monitoring the results of management trials is an important part of the learning process.

Contributing to the knowledge base on lichen abundance

The recommendations in this manual are based on analysis of only a few datasets. A larger database would serve two important functions:

- It would provide the basis for more complete recommendations about how to use the lichen abundance Field Guide as a tool.
- It would improve knowledge of the abundance and distribution patterns of arboreal lichens in caribou habitat.

Monitoring the effects of selection harvesting on lichen abundance

The Field Guide can be used as a monitoring tool as well as a planning tool. Assessments based on the Field Guide can be expected to detect only relatively large changes in lichen abundance. Changes that result from damage to trees during logging, or wind-scouring of trees after logging, should be detectable. Changes that result from faster or slower growth rates after logging would probably not be detectable, at least not for a long time.

To monitor lichen abundance in operational situations, carry out pre-harvest lichen assessments as usual. Permanently mark the plot or transect locations and the assessed trees so they can be relocated. If possible, mark and assess trees in an adjacent control area that will not be harvested. Wait at least a year after harvest to re-assess the trees.

Data resulting from lichen reassessment may be used to determine the effects of the harvesting on abundance in each Lichen Class. Statistical methods as described in Section 5 may be used to determine whether the prescription succeeded in maintaining the pre-harvest frequency distribution of lichen scores. If it did, statistical analysis should show no significant difference between frequency distributions before and after harvesting.

It is also important to assess the impact of the harvesting on overall lichen abundance. A simple way to do this is to compare the number of trees per hectare pre-and post-harvest in Lichen Classes ≥ 3. This type of information will help managers to know what relative change in lichen abundance to expect from various harvesting prescriptions. To express the change in absolute terms, lichen scores may be converted to biomass equivalents (Section 6) and plot totals calculated. It is also possible to track the fate of the lichens in a harvested block by identifying the sources of the

lichen loss. Figure 13 shows how two prescriptions used in an experimental selection harvesting block affected the amount of lichen lost through prescription harvest, road and landing rights-of-way clearing, and other sources, and the amount remaining after harvesting.

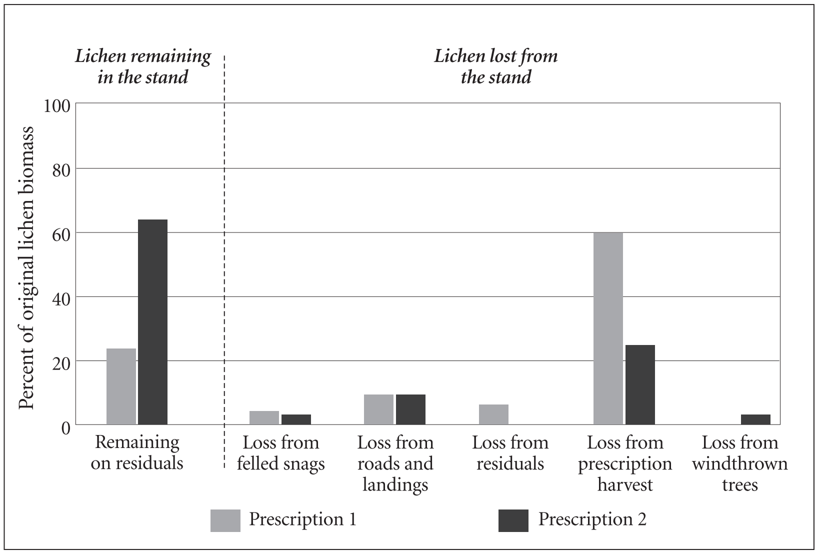


figure 13 *Effects of two selection harvesting prescriptions on post-harvest lichen abundance and losses.*

8 USING THE FIELD GUIDE FOR RESEARCH AND INVENTORY

Research

The Field Guide has a variety of uses in research, such as:

- studying the characteristics of habitats used by caribou
- studying the relationship between lichen abundance and environmental variables
- studying the effects of forestry practices on caribou habitat attributes

Sampling strategy for research purposes is likely to differ from sampling for forest management planning or operations. For planning or operational purposes, the sampling plan is mainly designed to quantify lichen abundance *per se*, and other factors (if sampled at all) are sampled contingently. For a research study, the sampling design will depend on the type of question being asked, the scale at which it applies, and the sampling requirements for variables other than lichen abundance. Since these considerations are bound to differ from case to case, comments here about sampling design are limited to a few basic generalities.

Lichen abundance data tend to be highly variable, and the sample characteristics tend to differ from site to site. Regardless of whether lichens are the main or the contingent variable, the main requirement of the sampling plan will be to gain as much control as possible over the

sources of this variation at the site in question. When each site differs, use of a "standard sampling plan" with a pre-ordained layout, sample size, and sampling method (transect or plot) is unlikely to achieve this.

Existing datasets have shown that much of the sample variation at any particular site is related to differences in spatial scale. Even when the site in general is rich in lichens, abundance often varies greatly at a local level. Differences from tree to tree within a single plot may be as large as between neighbouring plots, and not much less than the variation over the site as a whole.

Thus, if the study is to include broad-scale factors such as elevation or forest cover type, a total sample well in excess of 150 trees may be required if the role of these factors is to be detectable among local effects. The same may be true for the converse aim of detecting local effects (e.g., site class or light regime) if the sample has to be spread over a wide area to obtain enough trees in each category of interest.

At sites that are poor in lichens, on the other hand, plots tend to be more internally homogeneous, neighbouring plots more often resemble one another, and most of the variation is at a broader scale. Thus, fewer sample trees or plots may be needed per unit area; the more important factor will be their dispersion. Therefore, whenever practicable, a pilot survey of the site is advisable (see Section 5), to gauge the level of variation at different spatial scales before deciding how to distribute the sample among them.

If a reconnaissance confirms that the site is highly variable, stratifying the sample by tree types or classes may also help to reduce extraneous variation, provided that good strata can be defined. This is an important qualification, since strata that are mismatched to actual sources of variation will yield less efficient estimates than a simple random sample. From datasets that have been examined so far, few good stratification criteria have emerged. Some of the more consistent ones are:

- tree species
- wildlife tree class
- tree size (dbh class)
- age class (tree or stand)

Differences in such variables as tree characteristics within plots often account for much of the variation among plots. If sampling strata cannot be identified beforehand, post-stratification by these factors may be feasible, provided the resulting strata are not too small and the variation within them is less than the variation among them.[13]

To compile the data for analysis, the same basic steps described in Sections 4 and 5 apply. However, analyzing the data for research purposes is likely to extend beyond comparing sites or parts of sites, and the analytical methods will be more complex. To control for the multi-dimensional variation in lichen scores, log-linear modelling may be the method of choice, and for comparing lichen scores with external variables, logistic regression will be appropriate.

13 See: Yates, F. 1981. *Sampling methods for censuses and surveys.* Griffin, London, U.K.; or Cochran, W.G. 1977. *Sampling Techniques.* Wiley, New York, N.Y.

Inventory

The Field Guide methods have been incorporated into the vegetation inventory procedures[14] of the Resources Inventory Committee. If lichens are routinely included in surveys where caribou are known or suspected to occur, a large body of data may eventually result. This will increase knowledge of lichen abundance and distribution in more caribou ranges than at present.

9 CONCLUSION

Since the late 1980s, forest managers and researchers have been experimenting with timber harvesting methods that will better maintain arboreal lichens in mountain caribou habitat. Developing forestry practices that will allow timber harvesting and also maintain habitat for caribou is a large-scale and long-term undertaking. To a great extent, its success will depend on the willingness of managers to apply the principles of adaptive management. These include recognizing the present lack of knowledge about the effectiveness of various forestry practices in maintaining caribou habitat, deliberately designing experiments to test new practices, and using the results to modify management practices thereafter.

Using lichen abundance data for planning and monitoring purposes in caribou habitat areas is one way that managers can contribute to the process. The Field Guide for assessing lichen abundance was published for that purpose. It has been widely adopted, but users have experienced some frustration in trying to apply the assessments described in it. Although there are many unknowns still to be overcome, this handbook is an important step in making the Field Guide a more useful tool for assessing lichen abundance.

14 Vegetation Inventory Working Group. 1997. *Vegetation resources inventory ground sampling procedures.* B.C. Ministry of Forests, Resources Inventory Branch. Victoria, B.C. Draft, March 31, 1997.

DATA REGISTRATION FORM

Organization: ____

Address: ____

Contact person: ____

Telephone: ____________ Fax: ____________ E-mail: ________________

Name and location of project area

NTS: ____________________ UTM: ____________________

Biogeoclimatic subzone(s): ____

Purpose of project:

- ☐ reconnaissance (caribou habitat)
- ☐ cutblock planning (caribou habitat)
- ☐ cutblock monitoring
- ☐ research *Specify:* ______________________________
- ☐ inventory *Specify:* ______________________________
- ☐ other *Specify:* ______________________________

Area sampled *(e.g., three 40- to 60-ha blocks; 5,000-ha watershed):* ____________________

Brief description of sampling scheme *(e.g., prism plots systematically located in each of two strata):*

____

____

Total number of plots or transects: ______________________________

Year(s) and season(s) of sampling: ______________________________

Assessor's previous experience with lichen Field Guide:

☐ no previous lichen surveys ☐ 1–4 previous lichen surveys ☐ 5 or more previous lichen surveys

Did you collect data on the types of lichens present? ☐ yes ☐ no

Data format:

- ☐ field cards
- ☐ electronic spreadsheet *Specify type:* ______________________________
- ☐ electronic database *Specify type:* ______________________________
- ☐ cruise compilation
- ☐ other *Specify:* ______________________________

If requested, would you release your data to a central database? ☐ (Credit will be given if data are used.)

Comments: ____

____

Please mail or fax to:

Research Wildlife Habitat Ecologist
Ministry of Forests
Cariboo Forest Region
200 - 640 Borland Street
Williams Lake, BC V2G 4T1
Fax: (250) 398-4406

or

Wildlife Section Head
Ministry of Environment, Lands and Parks
Omineca-Peace Region
1011 Fourth Avenue
Prince George, BC V2L 3H9
Fax: (250) 565-6629